Renewable and Sustainable Energy Reviews 26 (2013) 769–775

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Location allocation of solid biomass power plants: Case study of Vojvodina

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ARTICLE INFO

Article history:
Received 8 August 2012
Received in revised form
22 June 2013
Accepted 24 June 2013
Available online 16 July 2013

Keywords:
Biomass
Electricity
Location
Allocation
Vojvodina

ABSTRACT

Vojvodina is an agricultural, energy-deficient province of Serbia. The Provincial authorities strongly encourage implementation of renewable energy sources, particularly electricity generation. Based on the biomass study about 5% of the total electricity consumption is targeted for generation from biomass, which can be obtained from a total power plant capacity of about 50 MW. The objectives of the research were to define power plants' locations, based on minimal electricity generation costs, and to investigate financial effects of increasing upper limit of power plants' capacity from the existing 10 to 15 MW. In order to meet the objectives, mapping of biomass potentials in Vojvodina was performed and the coefficient of availability was introduced to define biomass quantities available for this utilization. The mathematical model for solving the location allocation problem of solid biomass power plants for the region with defined biomass potentials and targeted total electric capacity has been developed. The model enables determination of capacity, type and location of solid biomass power plants by tending to facilitate minimal electricity generation costs. The results of the case study indicate that the specific investment costs for power plants have the biggest impact on the selection of power plant capacity and type, and therewith also on location. This is the consequence of the high density of agricultural biomass in Vojvodina and therefore shorter supply distances. Increase of power plant capacity from 10 to 15 MW reduced the average electricity generation costs by approximately 10%.

Contents

1. Introduction

The Province of Vojvodina is an agricultural part of the Republic of Serbia, situated in the Pannonia plane, with about 1.7 Mha of arable land and 0.1 Mha of forest. It is an energy deficient region, with limited reserves of oil, natural gas and coal. There is a

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http://dx.doi.org/10.1016/j.rser.2013.06.039

shortage of electricity because, according to the energy balance report of Vojvodina for 2011, only 1.9% of the total annual consumption (about 9000 GWh) is generated in the Province [1]. The Provincial authority, the Secretariat for Energy and Mineral Resources, strongly encourages implementation of renewable energy sources (RES) following EU policy and Directive 2009/28/EC, supported by national law and incentives. Electricity generation is particularly emphasized, encouraged by the issuing of the bylaw related to the provision of electricity generation from RES. It is based on the feed-in tariff for biomass, with limited upper capacity of biomass power plants to 10 MW.

Biomass is declared as the largest potential of RES in Serbia. According to the study performed at the national level [2], potential of the solid biomass in Serbia has been estimated to 2.7 Mtoe, whereby about 1.4 Mtoe is the agricultural residual biomass. Innovated assessment of agricultural biomass potential [3] is 1.7 Mtoe, which includes biomass from livestock production. Martinov et al. [4] defined the potential of solid biomass in Vojvodina to be 0.7 Mtoe, and forecasted its possible increase to 1.1 Mtoe by 2020, including short rotation coppices [5]. Crop harvest, pruning and primary processing residues dominate the category. The exact data of the current RES utilization, including biomass, however, are missing. According to the rough estimation, biomass used as fuel makes up 5–6% of the primary energy in the Province. Utilization of agricultural biomass for household heating in rural areas prevails.

Possibilities and potentials of the biomass utilization for combined heat and power (CHP) in Vojvodina are elaborated by Martinov et al. [6], and the future increase is forecasted by Dodic et al. [7]. Many problems are identified and one proposal is to apply electricity generation instead of cogeneration due to the plant location problem and lack of adequate heat energy consumers [6]. Compared to fossil fuels, agricultural biomass has lower specific price (per energy unit). However, the price may increase considerably with an increase of the biomass supply transportation distance and due to the storage costs. The power or CHP plants cannot be located in the vicinity of larger settlements or industrial thermal energy consumers, due to the lower resource density and higher transportation costs for the biomass supply. This is why the cogeneration study resulted with the proposal to set up several larger power plants, producing only electricity, with total installed power of 45–50 MW.

The mapping of biomass recourses is of crucial importance for defining type, size and location of power plants. Edwards et al. [8] did the inventory of cereal straw in European Union, followed by elaboration of logistic issues related to the localization of power plants. The mapping of almost all crop residues in European Union was performed by Scarlat et al. [9]. Similar mapping was done for Serbia [2] and Vojvodina [10]. Biomass density maps, and data with distances from biomass sources to potential locations of power plants, i.e., supply radiuses, were the output from the process enabling calculation of costs for biomass supply to the power plant storage.

The electricity generation costs in biomass power plants, excluding fuel purchased, depends on an investment and operational costs. Investment costs diminish with the increase of power plant capacity, i.e. nominal electrical power. On the other hand, higher capacities need a larger quantity of biomass feedstock to be supplied from the bigger area, i.e., longer distances. This is why determining an optimal location of a solid biomass power plant plays an important role for the efficient organization of the logistics activities and therefore the reduction of total costs. The other significant influence on investment costs plays the type of biomass utilized in a plant. Agricultural biomass, in comparison with the wooden residuals, has higher content of ash, nitrogen, potassium and chlorine, as well as lower ash melting point temperature. Therefore, its utilization requires specially adopted steam boilers, which have higher investment and operational costs. Mixing of wooden and agricultural biomass may reduce this problem. On the other side, amount of wooden biomass in Vojvodina is limited and its price is higher. Moisture content of biomass has also an influence on boiler selection. Biggest potential in Vojvodina presents maize stover, but moisture content of this biomass varies from 15% to over 50%. Overcoming this problem requires additional processes followed by additional facilities, increasing investment costs.

A large number of mathematical programming models for the wide range of location allocation problems has been developed and applied. However, only a few of them deal with the location problem of biomass facilities. Rogers and Brammer [11] were dealing with the location optimizing the transport costs of energy crops for their use in pyrolysis plant networks. Rentizelas et al. [12] analysed the logistics issues of biomass, particularly the storage problems and came to the conclusion that the application of a cheaper storage solution leads to significant cost reduction of biomass supply. A methodology for the biomass logistics and transport optimization, using Geographic Information Systems (GIS) has been suggested by Perpiñá et al. [13]. Their research concluded that an efficient biomass supply management could play an important role in minimizing transport distances, which would be important for the location selection. Kocoloski et al. [14] investigated impacts of facility size and location decisions regarding cellulosic ethanol production cost, concluding that the impacts can contribute substantially, up to 15–25% of the total costs.

The main objective of this research was to develop and test the mathematical model that may serve as a tool to determine capacities, types and locations of solid biomass power plants that create minimal electricity generation costs, for regions with identified biomass resources and targeted electricity generation. The model was tested for the case of the Province of Vojvodina.

The further objective was to examine the financial effect of the increase of power plant capacity limit from existing 10 MW to 15 MW, considering that Wiesenthal [15] proposed the range of 10–15 MW as an optimal (36 MW as maximal) capacity.

2. Materials and methods

The total costs of electricity generation can be divided to biomass supply and power plant costs. The biomass supply costs are influenced by many factors, but the most important are biomass density and size of the biomass supply area, i.e., distance between the biomass source (primary storage) and power plant location. The power plant costs depend on the power plant type and capacity.

The developed mathematical model optimizes location allocation of solid biomass power plants and defines their capacity and type in order to achieve the lowest electricity generation costs. The model can be applied for any defined region with known biomass potentials, distribution, and targeted total power plant electric power.

Within this paper, the model for the Province of Vojvodina, the agricultural region surrounded with non-agricultural areas and state borders, is tested. The planned annual electricity generation is 400 GWh, which can be obtained with the total power plant electrical capacity of 50 MW.

2.1. Biomass supply costs

Biomass supply costs are costs of the biomass available at power plant storage—PPS. PPS contains the biomass for about 2 weeks of power plant consumption and is supplied from primary storages,

located in the vicinities of biomass sources. Total supply costs consist of the price of biomass purchase at the primary storage (paid to farmers), costs of storing biomass at the primary storage (including handling), and transport costs between the primary storage and PPS (including unloading at PPS). Agricultural biomass is considered in the form of a big round or rectangular bales, and forest biomass in the form of wood chips. The characteristics of four considered biomass types are presented in Table 1.

Based on previous publications and novel statistical data on agricultural and forestry land for municipalities, as well the data presented in Table 1, the innovated mapping of agricultural and forestry biomass potentials of Province Vojvodina has been performed. Contrary to previous mappings, here the biomass densities are not expressed in tons per square kilometre, but as total available amounts of agricultural biomass for each of 45 municipalities. The available amount was calculated as a product of acreage of considered crops, average annual biomass yield and *coefficient of availability* for each municipality (Fig. 1). Due to different values of LHV, the biomass type K_3 is taken as representative, and for K_1 and K_2 reductions factors were applied (3.9/4.0 and 3.3/4.0, respectively). The *coefficient of availability* represents the share in larger plots and is introduced to eliminate those not suitable for collection of crop residues using contemporary technologies. It is presumed that the presses for big round and rectangular bales can be efficiently applied only for plots of 5 ha and more. The coefficients of availability have been defined for each municipality consulting the local authorities and extension services experts. For the same reason only the wooden biomass collected from forest areas over 2000 ha is taken into account.

Table 1
Characteristics of selected biomass.

Type	Biomass	Price[a] (€/t)	Average annual yield[b] (t/ha)	LHV[c] (MWh/t)
K_1	Maize stover, W=20%	30	4.0	3.9
K_2	Maize stover, W=30%	26	4.7	3.3
K_3	Straw[d], W=15%	38	3.0	4.0
K_4	Wood chips, W=35%	45	1.2	3.1

W: moisture content.

[a] Valid on primary storage in 2012, contracted purchase for amount over 100 Mg.

[b] Harvestable residual biomass, according to Martinov et al. [4].

[c] LHV: lower heating values are taken from diverse sources (for dry matter) and calculated for the defined moisture content, according to Kaltschmit et al. [16].

[d] In this group wheat straw is dominant, but soybean straw is considered as well, with slightly lower yield and higher LHV.

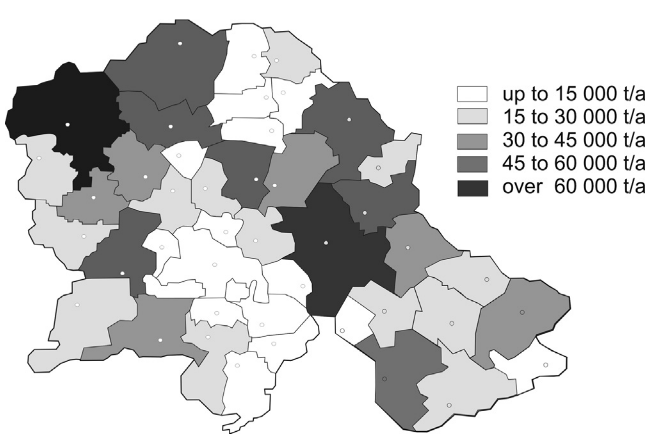

Fig. 1. Map of available agricultural biomass in municipalities of Vojvodina.

The primary storages are randomly distributed over municipalities' areas. In order to reduce the problem complexity, municipality centres are considered as local primary storage locations as well as the potential locations of the biomass power plants. The locations are used to define transport distances between primary storages and PPS.

Only open air primary storages are considered, whereby the stocked bales and wood chip piles are protected from precipitations by protective foil cover, made of material usable for several years. Storage costs include:

- land lease, different for each site (the prices differ between municipalities),
- costs of protective foil cover,
- handling—stocking and loading of transport vehicles (used outsourcing, equipment and labour), and
- fire insurance costs.

Land lease costs are in the range 0.5–2 €/m^2 a. The price of protective cover foil, usable for three years, is 2 €/m^2. For handling, the labour costs were taken 20 €/d (part time job with reduced taxes), and equipment costs, telescopic handler, 200 €/d. For the labour needed for handling, the data presented in Ref. [17] were used. Fire insurance cost at the open storage is 1.4% of the total annual value of the stored biomass.

Transport of biomass from the primary to PPS is performed by trucks. Loading of trucks is included in the storage costs. Average speed is 50 km/h and the load of biomass 11 t. Actual transport price, in the transport market in Vojvodina, for short distances and low density goods is 0.09 €/t km. Distances between centres were used for the calculation of transport costs between municipalities, while for the transport within municipalities average transport distances within were used. For the unloading and stocking of biomass at PPS, the same handling costs are used as for those on primary storages.

2.2. Power plant costs

The power plant costs consist of investment and operational costs.

Investment costs comprehend all investment costs for power generation plant comprising equipment and infrastructure, including biomass supply storage and electricity transmission network (connection to the grid).

For different biomass types and mixture of two biomasses, an adequate boiler with additional processing is needed, with mixing and feeding equipment. The six considered power plant types for biomass available in Vojvodina, according to maps obtained, are listed in Table 2. For all cases, steam-turbine type of power plant is considered.

The specific investment costs for power plant differ for diverse types and capacities. Here the power plants considered have electric capacity of 5–10 MW, with an increment of 1 MW. The

Table 2
Considered power plant types according to used biomass.

Type	Biomass
T_1	100% K_3
T_2	100% K_1 and/or K_2
T_3	50% K_3 and 50% K_1 and/or K_2
T_4	100% K_4
T_5	60% K_4 and 40% K_3
T_6	60% K_4 and 40% K_1 and/or K_2

capacity of 5 MW has been selected as the lowest limit based on the specific investment costs criteria, since below this limit costs significantly increase. The capacity of 10 MW is the upper capacity limit eligible for getting privileged feed-in tariffs for electricity generated from solid biomass and delivered to the public electricity transmission network (defined by Serbian national bylaw). Additionally, the power plant of 15 MW was considered in order to examine the effect of capacity limit increase to electricity generation costs. The electrical efficiency of a power plant increases with its capacity, influencing total electricity generation costs as well. For the electrical efficiency data presented by Hofbauer [18] and Scholwin and Thrän [19] were used.

Investment costs for different types and plant capacities per megawatt, as well as plant electrical efficiency coefficients, are given in Table 3. The data are based on Thek and Obernberger [20], and Obernberger and Thek [21].

Investment costs for auxiliary equipment include purchase of equipment for biomass handling (from PPS to the plant), processing and boiler feeding, electricity transfer connection to the public high voltage grid, ash collecting and disposal, fire and general security.

Costs are calculated based on the market prices and equipment used for specific biomass. If the mixture of biomass is used, the adequate necessary equipment is included. The costs for connection to the public grid depend on the distance, and are calculated for each potential location.

The plant exploitation lifetime is considered to be 15 years and the plants are expected to have 8000 operating hours a year. In order to reduce the problem complexity, plant depreciation costs and interest on investment loans were not taken into account.

Operational costs include the costs required for the operation of the power plant: boiler feeding, monitoring and control, maintenance, repairs, etc. They consist of material, labour and other costs (insurances, etc.), including also costs for ash disposal.

Material costs, according to Obernberger [22], on average, make 2.5% of the investment costs for the power plant and auxiliary equipment.

Labour costs are calculated based on the average monthly gross salary in Vojvodina, that, according to the Statistical Office of the Republic of Serbia, amounts approximately 500€, multiplied by nine, representing three workers working in three shifts.

Ash disposal costs include transport of 90% of the total amount to the primary storages, where it is offered free of charge to the farmers and used as fertilizer, transport costs of fine ash (10% of the total) to the landfill and its disposal costs.

Insurance costs are calculated 0.9% of the total investment costs, per year.

2.3. Mathematical model

Mathematical model for solving the location allocation problem of solid biomass power plants was developed. It is based on the fixed costs location model on the network with capacity constraints. The model was suggested by Balinski [23] and further developed by Current et al. [24].

Structurally, the model is created from nodes and arcs. The nodes represent primary storages and potential power plant locations. The arcs represent the existing transport connections between the nodes. In this model, $i=1,\ldots,I$ represents a set of resource locations, $j=1,\ldots,J$ a set of potential plant locations, $k=1,\ldots,K$ a set of considered biomass types and $t=1,\ldots,T$ a set of plants' capacity and types.

The variables used in the model are $X_j^t, Y_{ij}^k, Z_j^{t,k}$ and have the following interpretation:

$$X_j^t = \begin{cases} 1 & \text{if the plant type } t \text{ is located at the location} j,\ \ j\in J \\ 0 & \text{if not} \end{cases}$$

- Y_{ij}^k proportion of supply of the biomass type k from the resource location i to the plant located at location j, $0\le Y_{ij}^k\le 1$.
- $Z_j^{t,k}$ proportion of the biomass k used in the plant type t located at location j, $0\le Z_j^{t,k}\le 1$. Other parameters used in the mathematical model are:
- $Q_j^{t,k}$ required amount of biomass type k at the power plant type t located at j,
- C_i^k available amount of biomass type k at the resource location i,
- S_j^t capacity of the plant type t located at the location j,
- S predefined total capacity of all located plants (in this case 50 MW),
- $\mathrm{OH}_e{}^t$ operating hours of the plant type t per year (in this case 8000 h),
- $\mathrm{LHV}^{t,k}$ low heating value of biomass type k used in the plant type t,
- η^t electrical efficiency coefficient of the plant type t.

Let $\{(\pi_l^t, \varepsilon_l^{t,1}, \ldots, \varepsilon_l^{t,K}),\ l\in\Lambda^t\}$ be a list whose each entry $(\pi_l^t, \varepsilon_l^{t,1}, \ldots, \varepsilon_l^{t,K})$ satisfies $0\le\pi_l^t\le 1$, and $\varepsilon_l^{t,k}\in\{0,1\}$, where $\varepsilon_l^{t,k}$ indicates if biomass k can be used for producing π_l^t percent of energy at plant t.

The objective function is:

$$\mathrm{Min} \sum_{k\in K}\sum_{i\in I}\sum_{j\in J} A_{ij}^k Y_{ij}^k + \sum_{j\in J}\sum_{t\in T} B_j^t X_j^t$$

subject to:

$$\textstyle\sum_{t\in T} X_j^t \le 1 \qquad \forall\, j\in J, \tag{1}$$

$$Y_{ij}^k \le \textstyle\sum_{t\in T} X_j^t \qquad \forall\, i\in I, \qquad \forall\, j\in J, \qquad \forall\, k\in K, \tag{2}$$

$$\textstyle\sum_{j\in J} Y_{ij}^k \le 1 \qquad \forall\, i\in I, \qquad \forall\, k\in K, \tag{3}$$

$$\mathrm{Q}_j{}^{t,k} = \frac{S_j{}^t \times \mathrm{OH}^t}{\eta^t \times \mathrm{LHV}^{t,k}} \qquad \forall\, j\in J, \qquad \forall\, t\in T, \qquad \forall\, k\in K, \tag{4}$$

$$\sum_{l\in\Lambda^t} \pi_l^t \times Z_j^{t,k} \times \varepsilon_l^{t,k} \times \mathrm{Q}_j^{t,k} \le \sum_{l\in\Lambda^t} \varepsilon_l^{t,k} \sum_{i\in I} C_i^k Y_{ij}^k \qquad \forall\, j\in J, \qquad \forall\, t\in T, \qquad \forall\, k\in K, \tag{5}$$

$$\sum_k \varepsilon_l^{t,k} Z_j^{t,k} = X_j^t \qquad \forall\, j\in J, \qquad \forall\, t\in T, \tag{6}$$

$$\sum_{j\in J}\sum_{t\in T} X_j^t S_j^t \ge S \tag{7}$$

The objective function minimizes total costs of the electrical energy generation from biomass. Here, $A_{ij}{}^k$ represents the biomass supply costs which depend on the biomass type, quantity,

Table 3
Solid biomass power plants electrical efficiency coefficients and specific investment costs (million €/MW).

S[a]	5 MW	6 MW	7 MW	8 MW	9 MW	10 MW	15 MW
η_e [b]	0.22	0.23	0.24	0.25	0.26	0.27	0.30
T_1	3.10	3.00	2.83	2.66	2.49	2.38	1.83
T_2	3.25	3.04	2.87	2.70	2.53	2.42	1.87
T_3	3.30	3.09	2.91	2.74	2.56	2.45	1.89
T_4	2.84	2.65	2.50	2.35	2.20	2.10	1.62
T_5	3.00	2.81	2.65	2.49	2.33	2.22	1.72
T_6	3.00	2.81	2.65	2.49	2.33	2.22	1.72

[a] Power plant capacity.
[b] η_e electrical efficiency coefficient.

Table 4
Calculation results.

Upper capacity limit	10 MW	15 MW
Number of the located power plants	5	4
Selected types of the located power plants	T_1 and T_2	T_1 and T_2
Total electricity generation costs, for targeted 50 MW (million €)	30.8	27.8
Electricity generation costs, for targeted 50 MW (€/MWh)	77	69.5

geographical position and availability, as explained in Section 2.1; while B_j^t represents the power plant costs which depend on the number, type and capacity of the power plants, as explained in Section 2.2.

Constraint (1) allows only one plant to be located at particular location *j*, while constraint (2) ensures that biomass is transported only to the located plants. Logical constraint (3) assures that only available amount of biomass sort *k* from the location *i* can be allocated to the plant located at *j*. Constraints (4) and (5) define the minimal amount of biomass required to produce π_l^t% of energy in the power plant *t* and make sure that precise amount of biomass is transported to the plant type *t* located at *j*. With constraint (6), it is ensured that all envisaged combinations of biomass are considered. Constraint (7) assures that the total installed capacity in all located plants has to be equal or larger than the predefined one.

All constraints allow for every biomass sort to be provided to each potential plant and for the biomass from each location to be provided to more than one plant.

The described model, in numerous iterations, varies potential locations and for each potential location varies all considered numbers, types and capacities of the plant, as well as respective required biomass supply area, while calculating the total cost for each possible variant. The optimal solution is the combination of variables that ensures the lowest total costs.

The model was tested using the software LP solve 5.0.0.0 and the results of the tests are presented below.

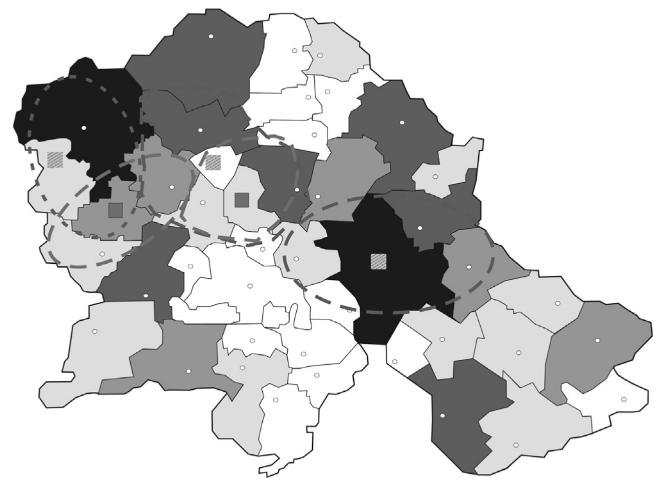

Fig. 2. Locations of solid biomass power plants and biomass supply areas for the power plant capacity limit of 10 MW.

3. Results and discussion

The developed mathematical model, in the case of Vojvodina, has 17,012 variables and 14,086 constraints. The calculation results obtained after more than 35 million iterations are given in Table 4 and further are separately presented for upper power plant capacity limits of 10 and 15 MW.

3.1. Maximal power plant capacity 10 MW

The planed total capacity was covered by five 10 MW power plants, three of type T_2, in municipalities Mali Idjos, Zrenjanin and Apatin, and two of type T_1, in municipalities Odzaci and Srbobran (Fig. 2). The average electricity generation costs are 77.0 €/MWh, and range from 75.0 €/MWh for the plant type T_2 located in Mali Idjos, to 80.0 €/MWh for the plant type T_1 located in Srbobran.

The calculation resulted with selection of power plant units with maximal capacity of 10 MW. Selected power plant locations are in municipalities where the average distances between PPS and primary storages with biomass feedstock are minimal. Obviously the reduction of specific investment cost for higher power plant capacities has more impact on electricity generation costs than increase of biomass transportation costs. This is also the implication of high biomass concentration – density, i.e. shorter transportation distances. In other words, transport costs in relation to transport distance increase less progressively than the investment costs in relation to plant's capacity. That is the reason why smaller number of plants with larger capacities is obtained as the result from the model.

Two types of solid biomass power plants were selected as the most adequate for the region of Vojvodina, T_1 and T_2. The power plant types using a mixture of two biomass types were not selected, although these types would have the smallest biomass supply area and therewith the lowest transportation costs. The reason for this is that the savings in transportation costs could not compensate for the increased investment costs with these types of power plants.

Biomass power plants that would use forestry residual biomass were not selected. This is due to the lower density and higher price of this biomass type, although the investment costs for power plants using wood are lower than the ones using agricultural biomass.

3.2. Maximal power plant capacity 15 MW

The calculation generated locations are presented in Fig. 3.

The planed total capacity was covered with three 15 MW and one 5 MW power plant. Two 15 MW power plants of type T_2 are located in municipalities Srbobran and Zrenjanin; one 15 MW of type T_1 in municipality Odzaci and one 5 MW type T_1 in municipality Apatin. The average electricity generation costs are 69.5 €/MWh, and range from 64.5 €/MWh for the plant type T_2 15 MW located in Zrenjanin, to 104.0 €/MWh for the 5 MW type T_1 capacity located in Apatin.

The results indicate that the existing capacity limit of 10 MW makes a significant influence on electricity generation costs, and

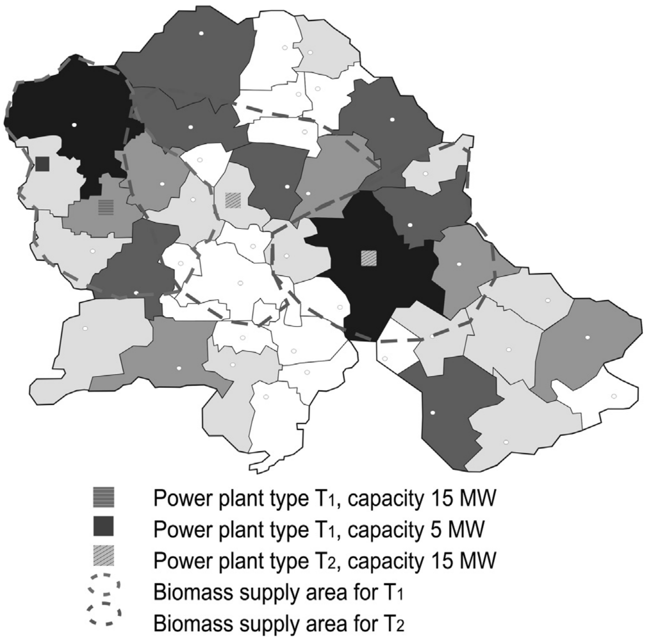

Fig. 3. Locations of solid biomass power plants and biomass supply areas for the power plant capacity limit of 15 MW.

that the capacity limit increase to 15 MW could reduce the average electricity generation costs for about 10%.

4. Conclusions

In order to solve the location allocation problem of solid biomass power plants the mathematical model was developed. The model varies all biomass sources, potential power plant types, capacities and locations searching for the combination of parameters that will result with the minimal electricity generation costs. The model was tested for the case of Vojvodina.

In Vojvodina, due to high density of agricultural biomass, the specific investment costs for power plants have the biggest impact to power plant capacity selection and location. This is why the maximal plant capacities were selected as optimal. For the selected maximal capacity power plants the biomass geographical density and biomass prices conditioned selection of the two power plant types: T_1 and T_2. None of the power plants using forestry residual biomass nor mixture of forestry and agricultural biomass were selected. Lower specific investment costs for wood biomass power plants do not result in lower electricity generation costs, due to the higher price and lower density of this biomass in Vojvodina.

The available biomass differs significantly between municipalities. Therefore the locations for the power plants were not assigned to the municipalities with the largest amount of available biomass but municipalities that have the minimal average distances between the plants and all primary storages assigned to cover the biomass demand.

The model did not consider the plant depreciation costs and interest on investment costs. Including these costs in the total costs calculation could only increase the impact of investment costs to the total electricity generation costs, which would not have significant influence on the obtained results regarding capacity, type and location of power plants. Resulted electricity generation costs, although calculated without interests on investment costs, are in the range that can enable profitability for investors. National feed-in tariff for this power plant capacity is 114 €/MWh, respectively 912,000 €/MW. The obtained results should be further elaborated with considered economic performances, including sensitivity analysis.

Comparison of costs for capacity limits of 10 and 15 MW showed that the higher capacity results in significant reduction of electricity generation costs, about 10%. The further increase of power plant capacity limit should be considered too. This, for the region with high biomass density, like Vojvodina, can result with further reduction of electricity generation costs.

Presented calculation results should be refined with energy and carbon dioxide balance, while longer transportation distances cause changes in overall balances. The selection of power plant micro location should also be further investigated, because it is influenced by many technical and environmental impacts including cooling possibilities, which in certain cases may have an important impact.

Acknowledgements

This work was funded by the Serbian Ministry of Science and Education (Project no. III42011).

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